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ABSTRACT

This paper presents the situation of women scientists in the United States in the fields of physics and astronomy. It gives a brief picture of the situation since the beginning of the 18th century and up to the start of this century. During the past 77 years, the percentage of participation of women in the two fields has fluctuated with a sharp increase in the last few years. The paper reveals that the rate of unemployment for women scientists in 1975 was four times higher than that for men, and that their salaries were consistently lower. However, recent increased percentages of physics doctorates awarded to women and the reversal on acceptable reasons for discriminating against women, coupled with changes in the societal views of appropriate roles for women, will make it easier for women to take themselves seriously as competitive scientists. The paper includes seven tables and five graphs to compare and explain data. (GA)

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Women in Physics and Astronomy

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Women in Physics and Astronomy

The situation of women scientists today is much more understandable when viewed from the perspective of history. In the United States, this history begins with a botanist, Jane Colden (1724-66), but there was a gap of nearly a century before our second well-known woman scientist, the astronomer, Maria Mitchell (1818-89), became internationally recognized. Higher education, unavailable to women in the 18th century, began to include them as the need for school teachers and the words of the first feminists touched the educational world, and simultaneously science ceased to be an avocation for the well-to-do and began to be taught and practiced in the universities. After the Civil War, college education of women blossomed and Maria Mitchell was followed at Vassar by her student, Mary Whitney (1847-1921), also an internationally recognized astronomer. At the Harvard College Observatory, Williamina P. Fleming (1857-1911) was followed by Annie J. Cannon (1863-1941) and Henrietta S. Leavitt (1868-1921),[1] a concentration of internationally recognized female scientific talent due to the influence of Professor Edward C. Pickering, director of the Observatory, who was also important in the career of one of the few notable women physicists of this period, Sarah F. Whiting (1847-1927).[1] She took a physics course with Pickering while he was still at M. I. T., which strongly influenced her later work at Wellesley. However, only one woman was among the physicists awarded stars indicating international recognition in the 1906 to 1921 editions of "American Men in Science", Margaret E. Maltby (1845-1926), a Barnard professor.

Margaret Rossiter[2] has given us a very detailed picture of the situation at the beginning of the 20th century. 2.6% of physicists and 6.4% of astronomers were women. Approximately half of these women (11/23 of women physicists and

11/21 of women astronomers) received their undergraduate education at women's colleges and virtually all the women physicists (21/23) were employed in women's colleges at some point in their careers. The majority of both women physicists and astronomers was employed in academia (18/23 and 21/21), a situation which was also true for the men in these fields, but half of the academic women astronomers (10/20) were employed in observatories, not as professors, and most of the professors were at women's colleges, not universities. Three of the twenty-three women physicists in Rossiter's study were secondary school teachers, whereas this was true of none of the men. It is also interesting to note that with the exception of two (10%) of the astronomers, none of the physicists or astronomers was married.[2] Pursuit of a scientific career required a dedication and determination precluding marriage which until the 20's generally enforced a subordinate role for the woman.

At the end of the 19th century a Ph. D. degree began to be a requirement for professional recognition. In Rossiter's sample, 65% of women physicists (vs. 71% of men) and 24% of women astronomers (vs. 41% of men) had Ph. D. 's.[2] The participation of women in these fields after 1920 is closely linked to the doctorate degree awards and one may trace this through the next five decades. Figure 1 shows that the number of physics doctorates awarded to women increased steadily from 1920 to 1969, but the percentage participation dropped from the 20's to the 50's due to the more rapid increase in the number of men. It is interesting to note that in 1920, 19% of the physics doctorates were awarded to women (4/21), whereas in the 50's this was true of only 1.8% of the doctorates.[4] The numbers in astronomy fluctuated about 15 up to the sixties and then rose to 37. However, the percentages dropped from 27% in the 20's to 6.5% in the 50's. The large increase

in the 40's is due to a small total number of astronomy doctorates, presumably associated with the war years. The decreases in percentages can be traced to the breaking of the first wave of feminism with achievement of suffrage and the changes brought about by the 20's. Neither the depression nor World War II was a good climate for increased scientific participation by women and the back-to-the-home enthusiasm following the war was devastating.

The renaissance of feminism in the late 60's led to, among other things, a desire to understand and improve the situation and this resulted in studies on the participation of women by committees of the American Physical Society and the American Astronomical Society in the early 70's.[4, 5] Both studies described a situation that was little changed from that described by Rossiter's study for the period before 1920. Women physicists were still employed mainly in academia and still were found more frequently in the lower faculty ranks and non-faculty positions and at the less prestigious institutions. Both studies found that a larger percentage of women than of men suffered from involuntary unemployment and underemployment and that the average salaries of women were lower. An interesting difference from the situation before 1920 is that the majority of women physicists and astronomers in the studies was married, although the percent unmarried was greater than the norm. The conclusion was drawn that overt discrimination had played an important role in the differences observed between women and men, as well as prevalent societal attitudes and practical problems of combining career and marriage.

The early 70's were marked by the beginnings of affirmative action and it is interesting to see what changes have occurred in the last seven years. Figure 2 shows the number and percent of the doctorates in physics and astronomy/astro-

physics awarded to women in this period, as well as the averages for the 1960-69 period. Because of the small numbers, the data for astronomy and astrophysics are not presented separately, and because of the overlap between these fields, astrophysics is presented with astronomy rather than as part of physics. (Astrophysics was only recorded as a separate doctoral field for a few years before 1970.[3]) The numbers and percentages for physics exhibit overall increases, the difference between 1975 ($5.0 \pm 0.7\%$) and 1976 ($4.0 \pm 0.6\%$) not being statistically significant. In astronomy/astrophysics, the numbers are approximately constant until 1975 and 1976 when there is a significant increase, whereas the percentages drop and then increase dramatically. It should be kept in mind that the uncertainties on the percentages are large (in 1975, $9.2 \pm 2.6\%$, and in 1976, $7.3 \pm 2.2\%$), but the patterns for physics and astronomy do seem to be somewhat different.

In an attempt to understand the reasons for participation patterns, one can ask whether participation by women is related to overall popularity of a field. Table I presents the percentages of doctorates in the various subfields of physics awarded to women in 1960-69 and 1970-76, as well as the percentages of all doctorates which were awarded for work in those subfields. Astronomy/astrophysics are also shown and the total number of doctorates awarded per year in astronomy increased by 139%, whereas that in physics increased by 47%. The average percentage of degrees in physics awarded to women rose by 79%, whereas that in astronomy/astrophysics remained constant. The change in physics is seen to be due to increases in most subfields without any significant correlation with the changes in popularity. The percentage of astrophysics doctorates awarded to women is seen to lie between those for physics and astronomy, and this grada-

tion can be explained by the greater attraction that descriptive fields have had for women than the purely quantitative. Certainly in the past the so-called "hard" sciences have been considered unfeminine in this country and it is well documented that there have been powerful societal pressures on young women to avoid such studies. The recent increase in the percentage of physics doctorates awarded to women apparently does not come from an increase in the number of women entering graduate study, but rather from a greater percentage who persevere to the doctorate level. In the past women were twice as likely to stop with a master's degree,[4] perhaps perceiving no reason for continuing in the limited employment possibilities open to them.

Table II gives the numbers and percentages of doctoral scientists employed in physics and astronomy in 1971, 1973, and 1975 who were women. Both numbers and percentages have risen steadily. It is seen that somewhat more of the women were foreign citizens than was true of the men. Table III gives the employment status for these scientists in 1971 and 1973. In both surveys, the percentages of women who were part time or unemployed are significantly greater than those for men, and the latter percentages are greater in 1973 than in 1971. Furthermore, if one combines the percentages of those unemployed seeking employment and part-time seeking full-time, it is seen that in 1973, 14% of the women (vs. 2.5% of the men) were looking for jobs. Comparisons of the data for doctoral scientists and engineers in all fields in 1973 and 1975 carried out by Maxfield, Ahern and Spisak[9] and Gilford and Snyder[7] have indicated a substantial decrease in the unemployment rate for women in this period. The percentages of doctoral scientists and engineers desiring but not holding full-time employment in science and engineering were 1.8% and 1.6% for men and 8.8% and

6.4%[7] for women in 1973 and 1975, respectively. Thus, in spite of the decrease, the percentage of women seeking employment remained four times that for men. Figure 3, taken from the Maxfield, Ahern and Spisak[9] study, gives the percentage of the science and engineering labor force who were unemployed and seeking employment as a function of calendar year of doctorate. It is interesting to note that the largest involuntary unemployment rates pertain for women 3-5 years away from their doctorates and thus presumably just completing their first postdoctoral positions.

Table IV gives the distribution of men and women physicists and astronomers with respect to type of employer. In both fields, the percentage of women in educational institutions is greater than that of men, and the 1973 percentages are greater for astronomy than for the combined fields. The percentages in educational institutions for the combined fields decrease between 1971 and 1973, with corresponding increases in the percentages in government and nonprofit employment. Furthermore, the percentage of men in industry decreased, whereas that of women increased very slightly. It should be noted that the percentages of doctoral women in these fields who taught in junior colleges and secondary schools in 1973 are larger than those for men. However, the study of Law et al. of women high school physics teachers showed that such individuals are a small minority and, in fact, most women high school physics teachers do not have any physics degree.[10]

Table V gives the mean salaries for men and women for the various types of employers and the salaries are consistently lower for women. In both the physics and astronomy studies, it was found that further subdivision of the sample did not remove the differences[4, 5] and an examination of the 1975 data for all

fields combined showed that this was still true for all age groups at this later date.[11]

Since the major employer of physicists and astronomers is the educational institution, it is interesting to examine the situation there more closely. Table VI presents the number and percentage of women in various types of physics departments in 1971-72[4] and in 1977-78.[12] It is seen that the changes in percentage either have been slight or where they appear substantial, due to a very small number. Furthermore, the overall effect is a decrease. It should be noted that except for the "Top Ten" category, the institutions in the various categories are not the same in the two years studied and thus the changes in percentage and number are a composite of changes in degree granting type and changes in the employment of women. Table VII presents similar data for selected astronomy departments and again the big change, that at the assistant professor level, is due to small numbers.

Thus, the overall impression is that statistically the situation of women physicists and astronomers has not changed very much either since the beginning of this century or in the last seven years. However, this is not quite true. The increased percentages of physics doctorates awarded to women now correspond to respectable numbers and it will not be long before they become commonplace enough in physics so that most physicists will know a competent woman as a colleague. Furthermore, affirmative action has caused a reversal on the acceptable reasons for discriminating against women, which once were readily and even righteously voiced. Even though this does not mean that discrimination has ended, the perceived change in climate will make it easier for women to take themselves seriously as competitive scientists. This in turn will result in a new

generation of male scientists who are much less likely to be prejudiced on the basis of sex.

Equally important are the changes in the societal views of appropriate roles for women. Admittedly, the progress here is uneven, but I do not think that there can be a pre-teenage girl whose family owns a television set who views marriage and motherhood as her sole exclusive option even though this may be the only option of interest to her. She knows that, like her male counterparts, she has a choice. Coupled with this is a widening of the possibilities open to a high school girl which should result in increases in the numbers who take physical sciences and advanced math in high school and who can therefore consider such majors in college. Again, the changes are slow, but coupled with the trend toward a society where the majority of women are employed outside of the home for a major part of their adult lives, they should lead to much more substantial participation by women in physics and astronomy.

It is tempting to end this paper on the optimistic note of the preceding sentence. However, there is also a pessimistic factor that must be mentioned. This is the combination of the increasing cost of scientific work in these fields, due to the dependence on rapidly changing technology, together with the much slower increase or lack of increase of funding for basic science. In my opinion, the result of this situation will not be unemployment as much as changes in employment patterns as the competition for prestigious university positions and others permitting basic research become increasingly fierce. In this competition, women will still be handicapped to some degree by surviving discriminatory attitudes, and to a much greater degree if they are not single-minded in their pursuit of a career. Roles in marriage are currently being rethought and changed, but even

if the responsibilities are divided equally between both partners, each is still at a disadvantage with respect to the individual who has no responsibilities outside of his or her career or who has a completely supportive partner, situations which I believe will continue to be much more common for men than for women. However, the saving facet of this situation is the growing awareness that many young physicists and astronomers will have to turn to applied and nontraditional fields for employment and a simultaneous increase in the possibilities. Employment in these fields may initially be considered much less prestigious than becoming a younger edition of one's doctoral thesis advisor and consequently lend themselves more readily to a lifestyle in which personal relationships are an important component. There will always be women who manage to combine brilliant and highly competitive careers with happy families, but I think the less demanding situations will continue to attract many women, particularly those with young children. And I think that this is as it should be. Women scientists should not all be required to be superwomen, just as the majority of men scientists are not required to be Einsteins.

Footnotes

1. "Notable American Women 1607-1950," Edward T. James, ed., The Belknap Press of Harvard University Press, Cambridge, Mass. (1974).

2. M. W. Rossiter, American Scientist 62, 312 (1974).

3. "Doctorates Awarded from 1920 to 1971 by Subfield of Doctorate, Sex and Decade," National Academy of Sciences (1973).

4. "Women in Physics," report of the Committee on Women in Physics of the American Physical Society, Bull. Am. Phys. Soc. II, 17, 740 (1972).

5. "Report to the Council of the AAS from the Working Group on the Status of Women in Astronomy - 1973," Bull. Am. Astro. Soc., 6, 412 (1974).

6. "Summary Report (Year). Doctorate Recipients from U. S. Universities," National Academy of Sciences, for the years 1972-73, 1973-74, 1974-75, 1975-76, and 1976-77.

7. "Women and Minority Ph. D.'s in the 1970's: A Data Book," D. M. Gilford and J. Snyder, National Academy of Sciences (1977).

8. "Women Doctoral Scientists in the United States (1973)," Vera Kistiakowsky, unpublished.

9. "Employment Status of Ph. D. Scientists and Engineers 1973 and 1975," B. D. Maxfield, N. C. Ahern, and A. Spisak, National Academy of Sciences (1976).

10. "A Study of Women High School Teachers," M. E. Law, J. Wittels, R. Clark, and P. Jorgenson, Bull. Am. Phys. Soc. 21, 888 (1976).

11. "Doctoral Scientists and Engineers in the United States, 1975 Profile," Board on Human-Resource Data and Analyses, National Academy of Sciences (1976).

12. Data compiled from the "1977-78 Directory of Physics and Astronomy Faculties," American Institute of Physics (1977).

13. The top ten in 1970 according to the American Council on Education: Berkeley, California Institute of Technology, Chicago, Columbia, Cornell, Harvard, Illinois, Massachusetts Institute of Technology, Princeton, and Stanford. The same institutions were included in the 1977-78 study.

14. The top five in 1973 according to ref. 5: California Institute of Technology, Princeton, Berkeley, Chicago, and Harvard. The last four of these were included in the 1977 study since the Cal Tech astronomy faculty could not be identified.

15. The top fifteen in 1973 according to ref. 5: those in ref. 14 plus Arizona, Cornell, Maryland, Massachusetts Institute of Technology, UCLA, Columbia, Texas, Michigan, Washington, and Yale. M. I. T. was not included in the 1973 study and neither M. I. T. nor Cal Tech was included in the 1977 study since the astronomy faculty could not be identified.

Table I

Percent (Number) of Doctorates Awarded in Various Subfields of Physics and in Astronomy/Astrophysics and Percent of Doctorates in Given Subfield Awarded to Women in 1960-69[3] and 1970-76[6].

	Percent of Total in Subfield		Percent of Subfield Awarded to Women	
	1960-69[3]	1970-76[6]	1960-69[3]	1970-76[6]
Physics Fields in which Participation Increased				
Physics, General	6.2%	12.5%	3.2 ± 0.7%	4.4 ± 0.6%
Plasma	0.7	5.5	0	1.3 ± 0.5
Optics	1.1	2.4	2.0 ± 1.4	2.6 ± 1.1
Physics Fields in which Participation Decreased				
Atomic	11.0	9.6	2.1 ± 0.5	2.4 ± 0.5
Elementary Particle	16.8	14.1	2.3 ± 0.4	3.8 ± 0.5
Fluids	3.0	1.7	3.0 ± 1.0	3.1 ± 1.4
Nuclear	17.1	12.8	1.6 ± 0.3	3.0 ± 0.5

Table I

(continued)

	Percent of Total in Subfield		Percent of Subfield Awarded to Women	
	1960-69[3]	1970-76[6]	1960-69[3]	1970-76[6]
No Change				
Acoustics	1.0	1.1	1.0 ± 1.0	1.8 ± 1.3
Mechanics	0.7	0.4	0	5.3 ± 3.7
Physics, Other	11.2	11.3	2.3 ± 0.5	3.4 ± 0.6
All Fields of Physics	(9285)	(9584)	1.9 ± 0.14	3.4 ± 0.19
Astronomy/Astrophysics				
Combined	(538)	(900)	6.5 ± 1.1	6.6 ± 0.9
Astronomy		47.8		8.4 ± 1.4
Astrophysics		52.2		4.9 ± 1.0

Table II

Percent (Number) of Doctoral Scientists Employed in the Fields of Physics and Astronomy who were Women by Citizenship and Year of Survey.

	1971[4]	1973[7]	1975[7]
Native Born U. S. Citizens		2.1(281)	2.4(334)
Foreign Born U. S. Citizens		2.1(39)	2.4(50)
Foreign Citizens		3.5(59)	3.0(46)
Citizenship Unknown		4.0(6)	4.9(10)
Total	2.1(347)	2.3(385)	2.5(440)

Table III

Percent (Number) of Men and Women Doctoral Physicists and Astronomers by Employment Status in 1971[4] and 1973[8].

Employment Status	1971[4]		1973[8]	
	Men	Women	Men	Women
Full-time	95%	73%	94%	66%
Part time	2.0	16	1.7	16
Seeking full time			0.8	7
Not seeking			0.9	9
Unemployed	1.3	9	2.1	13
Seeking employment	1.2	5	1.7	7
Not seeking	0.1	4	0.4	6
Retired, other	1.5	2	2.6	5
Total Number	(16,284)	(347)	(17,481)	(471)

Table IV

Percent (Number) of Men and Women Doctoral Physicists and Astronomers by Employer in 1971[4] and 1973[5, 8].

Employer	Physicists and Astronomers				Astronomers	
	1971[4]		1973[8]		1973[5]	
	Men	Women	Men	Women	Men	Women
Educational Institution	60%	77%	56%	67%	62%	77%
Ph. D. Granting			41	44		
University					56	65
M. A. Granting			5	4		
4-year College					4	6
B. A. Granting			9	15		
Jr. College			1	3	2	6
Secondary School			0.3	1		
Government	9	9	15	16	18	10
Industry	26	9	21	10	6	2
Nonprofit	3	3	5	4	9	4
Other	2	2	3	3	5	6
Total Number	(15,867)	(308)	(16,689)	(387)	(510)	(49)

Table V

Mean Salaries of Men and Women Doctoral Physicists and Astronomers by Employer in 1971[4] and 1973[5, 8].

Employer	Physicists and Astronomers				Astronomers	
	1971[4]		1973[8]		1973[5]	
	Men	Women	Men	Women	Men	Women
Educational Institution	$13.5K	$12.2K	$19.1K	$16.6K	$17.0K	$12.9K
Government	19.8	18.4	23.2	21.1	22.5	*
Industry	20.0	18.4	23.8	21.7	20.3	*
Nonprofit	19.2	13.1	21.0	16.2	19.4	*

* Too few individuals to be significant

Table VI

Percent (Number) of Faculty in Physics Departments who were Women by Rank in 1971-72[4] and 1977-78[12]

Department Type/Rank	1971-72[4]	1977-78[12]
"Top Ten"[13]		
All Professors	0.8 (4)	2.1 (10)
Full Professor	0.6 (2)	0.6 (2)
Associate Professor	1.1 (1)	5.8 (3)
Assistant Professor	0.9 (1)	5.5 (5)
Ph. D. Granting - Number of Departments	(158)	(220)
All Professors	1.5 (74)	1.4 (77)
Full Professor	1.0 (23)	0.9 (28)
Associate Professor	1.8 (24)	2.0 (30)
Assistant Professor	2.0 (27)	2.5 (19)
M. A. Granting - Number of Departments	(133)	(126)
All Professors	2.3 (28)	2.0 (23)
Full Professor	1.9 (7)	1.5 (8)
Associate Professor	2.2 (9)	2.1 (9)
Assistant Professor	2.6 (12)	3.2 (6)
B. A. Granting - Number of Departments	(743)	(602)
All Professors	5.4 (144)	4.2 (103)
Full Professor	5.8 (55)	2.9 (26)
Associate Professor	4.9 (33)	3.4 (32)
Assistant Professor	5.2 (56)	7.4 (45)

Table VI

(contd.)

Department Type/Rank	1971-72[4]	1977-78[12]
All Three Types - Number of Departments	(1034)	(948)
All Professors	2.8 (246)	2.3 (203)
Full Professor	2.4 (85)	1.4 (62)
Associate Professor	2.7 (66)	2.5 (71)
Assistant Professor	3.3 (95)	4.5 (70)

Table VII

Percent (Number) of Faculty in Selected Astronomy Departments who were Women by Rank in 1973-73[5] and 1977-78[12]

Department Type/Rank	1972-73[5]	1977-78[12]
"Top Five"[14]	0%	2% (1)
Professor	0	0
Associate	0	0
Assistant Professor	0	12 (1)
"Top Fifteen"[15]	4	5 (9)
Professor	4	4 (4)
Associate Professor	5	2 (1)
Assistant Professor	0	11 (4)

Figure Captions

Fig. 1: The number and percent of doctorates granted to women in physics and astronomy in each decade from 1920 to 1969. (Data taken from ref. 3.)

Fig. 2: The number and percent of doctorates granted to women in physics and astronomy/astrophysics in each year from 1970-71 to 1976-77 compared with the average values for 1960-69. (Data taken from refs. 3 and 6.)

Fig. 3: Unemployment rates by calendar year of Ph. D. for male and female Ph. D. 's. (Figure taken from ref. 9.)

Fig. 1

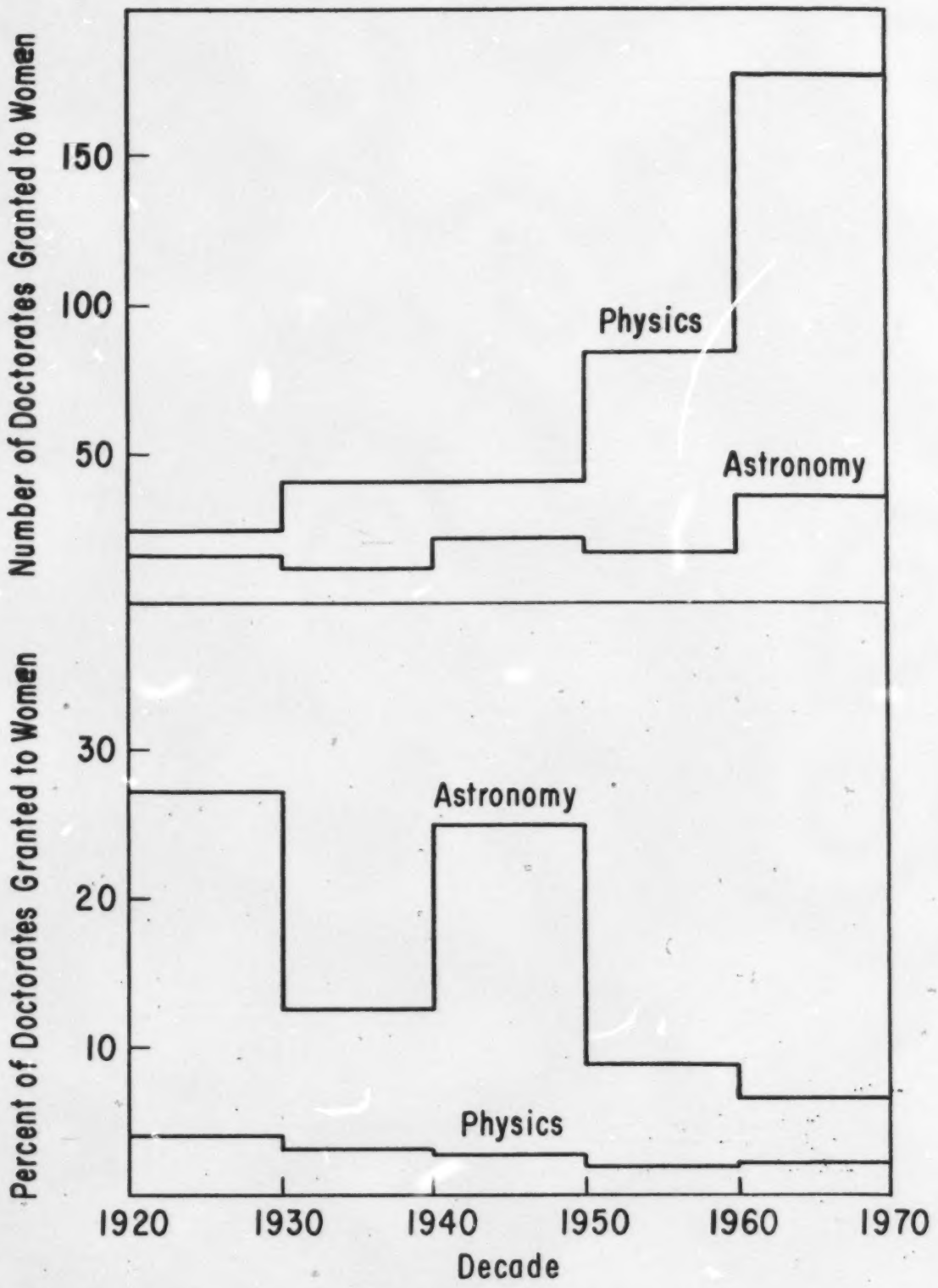
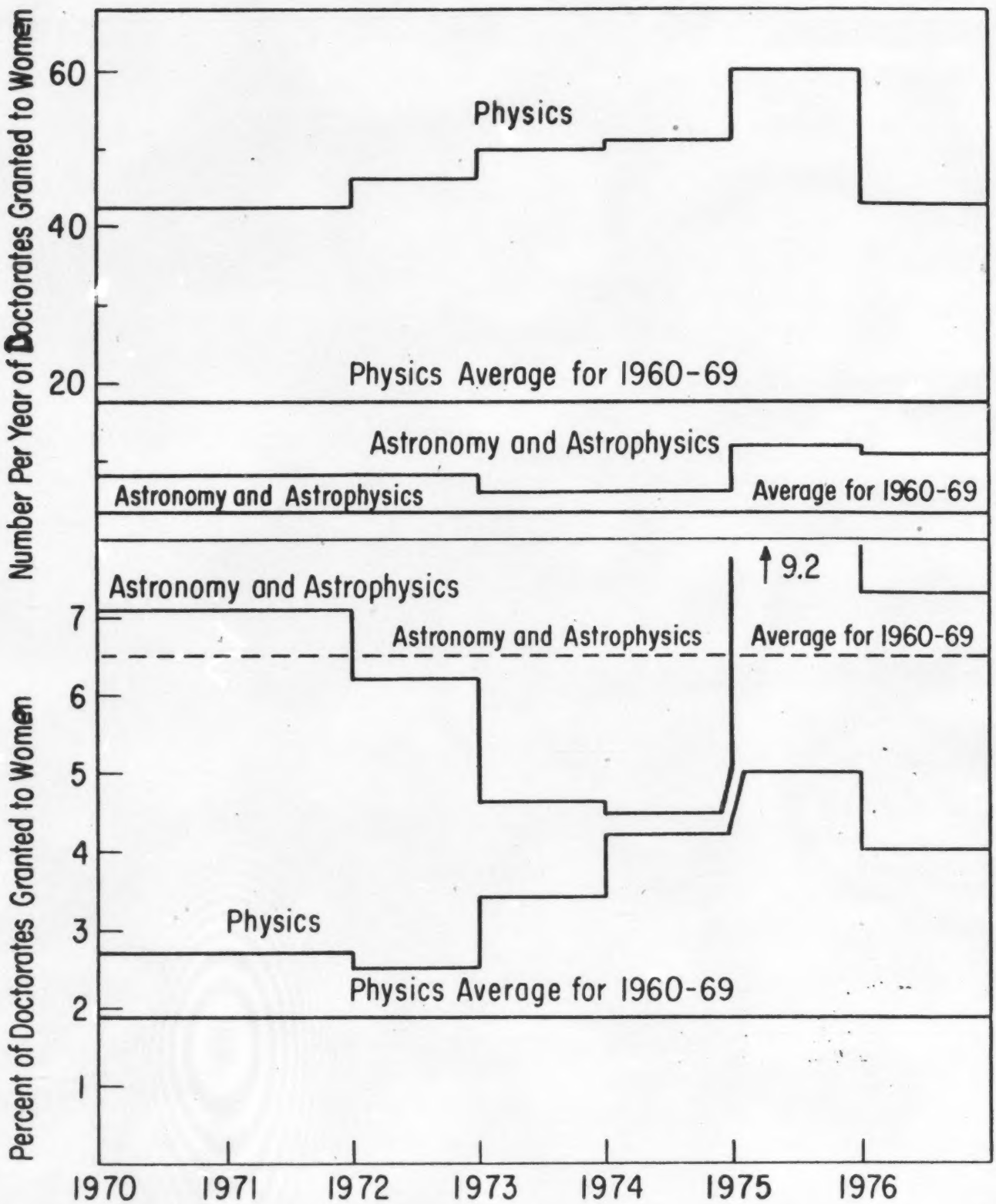
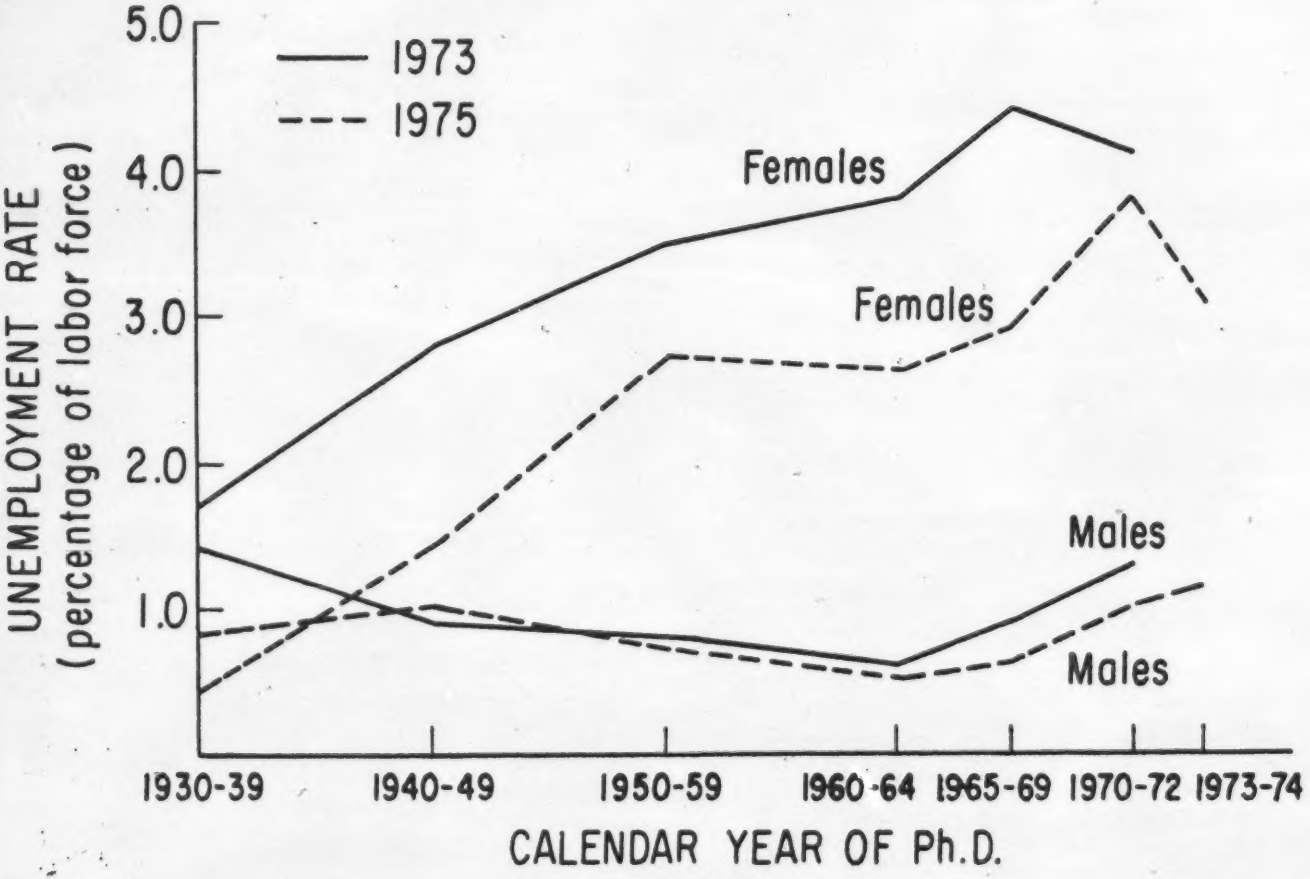

Number of Doctorates Granted to Women
150
100
50
Physics
Astronomy
Percent of Doctorates Granted to Women
30
20
10
Astronomy
Physics
1920
1930
1940
1950
1960
1970
Decade

Fig. 2


Number Per Year of Doctorates Granted to Women
60
40
20
Physics
Physics Average for 1960-69
Astronomy and Astrophysics
Astronomy and Astrophysics
Average for 1960-69
9.2
Astronomy and Astrophysics
Astronomy and Astrophysics
Average for 1960-69
Percent of Doctorates Granted to Women
7
6
5
4
3
2
1
Physics
Physics Average for 1960-69
1970
1971
1972
1973
1974
1975
1976


5.0
4.0
3.0
2.0
1.0
UNEMPLOYMENT RATE
(percentage of labor force)
1973
1975
Females
Females
Males
Males
1930-39
1940-49
1950-59
1960-64
1965-69
1970-72
1973-74
CALENDAR YEAR OF Ph.D.